INSPECTING METAL PIPE & PIPE-ARCH

Commentary to aid inspection of Steel & Aluminum Pipe & Pipe-Arch conforming to Section 02610 of the UDOT Specifications

First: review the Contractors Submittals:

Check the Certificates of Compliance documenting materials properties & coating thickness. These Certificates should key to the AASHTO reference specifications found in the following abbreviated version of Table 5 for the size/type of metal pipe delivered to the project site.

Verify Corrosion Classifications. Class A Pipe are only used in non-reactive soils that requires no special materials, treatments, or coatings. Class B Pipe are used in moderately reactive and corrosive soils and Class C Pipe used in soils that are highly reactive and corrosive.

Certificates of Compliance documenting that pipe joints can sustain 3 psi minimum pressure for all cross culverts and 5 psi minimum pressure for all storm-drains and irrigation pipes. Note-These Certificates should reference ASTM D 3212.

Abbreviated Version of Table 5

AASHTO Reference Specifications for Metal Pipe & Pipe Arch			
Pipe Type	**Pipe Corrosion Class**		
	A	**B**	**C**
Substitutions: Class B and C may be substituted for Class A, Class C may be substituted for Class B or A,			
Corrugated Pipe and Pipe Arch:			
Corrugated steel pipe. Corrugated steel pipe arch. **(1)**	M 36	M 36 Polymeric Coating 0 µm (inside)/250 µm (outside) M 245 & M 246 ASTM A 849 or Aluminized Type II Steel M 274 (2)	M 36 Polymeric Coating 250 µm (inside)/250 m (outside) M 245 & M 246 ASTM A 849

AASHTO Reference Specifications for Metal Pipe & Pipe Arch			
Pipe Type	**Pipe Corrosion Class**		
	A	**B**	**C**
Substitutions: Class B and C may be substituted for Class A, Class C may be substituted for Class B or A,			
Corrugated aluminum pipe. Corrugated aluminum pipe arch. **(1)**	M 196 M 197	M 196 M 197	M 196 M 197
Corrugated polyethylene (HDPE) pipe	M 294 ASTM D 3350	M 294 ASTM D 3350	M 294 ASTM D 3350
Smooth-Lined Pipe and Pipe Arch:			
Concrete lined corrugated steel pipe (Use Type V cement. Refer to Section 03055)	M 36	M 36 Polymeric Coating 250 µm (inside)/250 µm (outside) M 245 & M 246 ASTM A 849	M 36 Polymeric Coating 250 µm (inside)/250 µm (outside) M 245 & M 246 ASTM A 849
Spiral rib steel pipe Spiral rib steel pipe arch	M 36	M 36 Polymeric Coating 0µm (inside)/250 µm (outside) M 245 and M 246, ASTM A 849 or Aluminized Type II Steel M 274 (2)	M 36 Polymeric Coating 250 µm (inside)/250 µm (outside) M 245 and M 246 ASTM A 849
Spiral rib aluminum pipe and pipe arch	M 196 and M 197	M 196 and M 197	M 196 and M 197
Footnotes: (1) Minimum corner radii conforming to the details shown on the standard drawings. (2) Acceptable Soil Conditions, Class B, Aluminized Type II Steel are: 16 gage minimum thickness of metal acceptable where pH is greater than 7 and less than 8.5, and soil resistivity is greater than 1500 ohm-centimeters.			

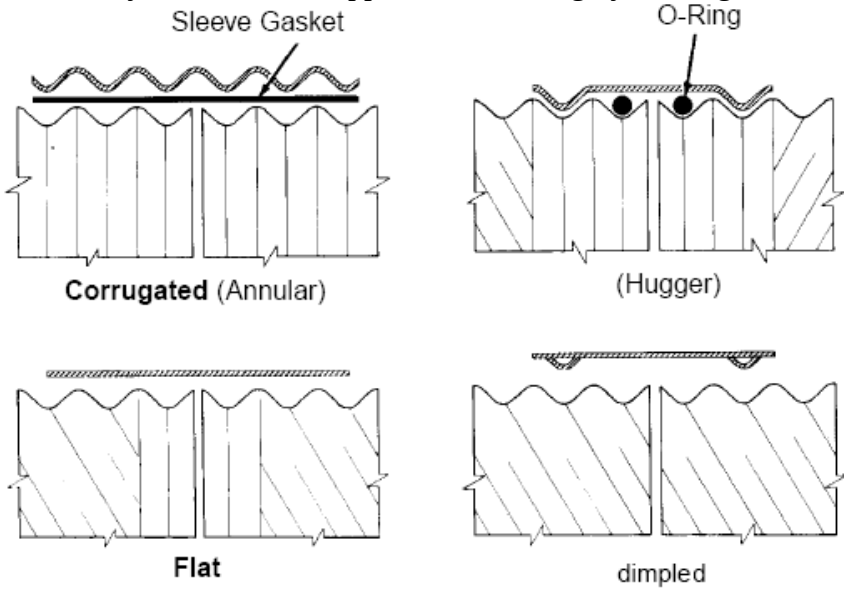
<u>Second:</u> Verify storm drain & irrigation pipe joints meet the 5 psi water tight criteria & that cross culverts meet the 3 psi criteria.

Examine the manufacturer's recommended drawing for a 5 psi joint for use with storm-drain and irrigation pipes for each pipe type on the project. If you do not have a copy of these drawings then request a copy from the Contractor as part of the pipe submittals.

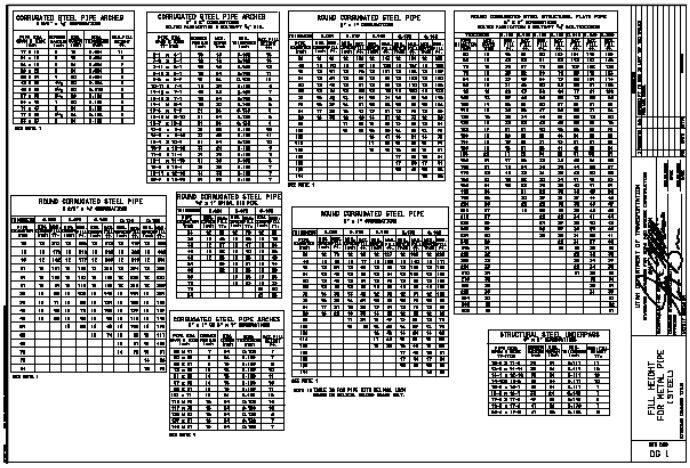
Similarly examine both the plans and the manufacturer's recommendations for connecting pipe lengths together and for connecting pipes to concrete headwalls, catch basins, and similar structures for any conflicts. Resolve any differences before construction begins.

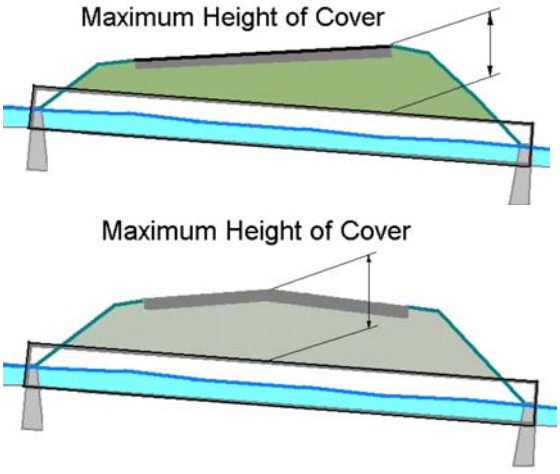
When Connecting Bands are used check the following:

a. Verify that the corrosion Class (A, B, or C) matches the pipe. Hint: If the pipe has an extra protective coating then the connecting bands also need to be coated.
b. Verify that connecting bands are at least 0.064 inch thick (16 gage).
c. Only use dimple bands when extending existing pipes where annular corrugations do not exist. Dimple bands make poor joints. Hint: If the pipe being extended is an irrigation pipe then consult with the Resident Engineer to see if the joint leakage will be acceptable.
d. Verify that the ends of helically corrugated pipe have been re-rolled to form at least two full annular corrugations at each end.
e. Flat bands can only be used when approved in writing by the Engineer.



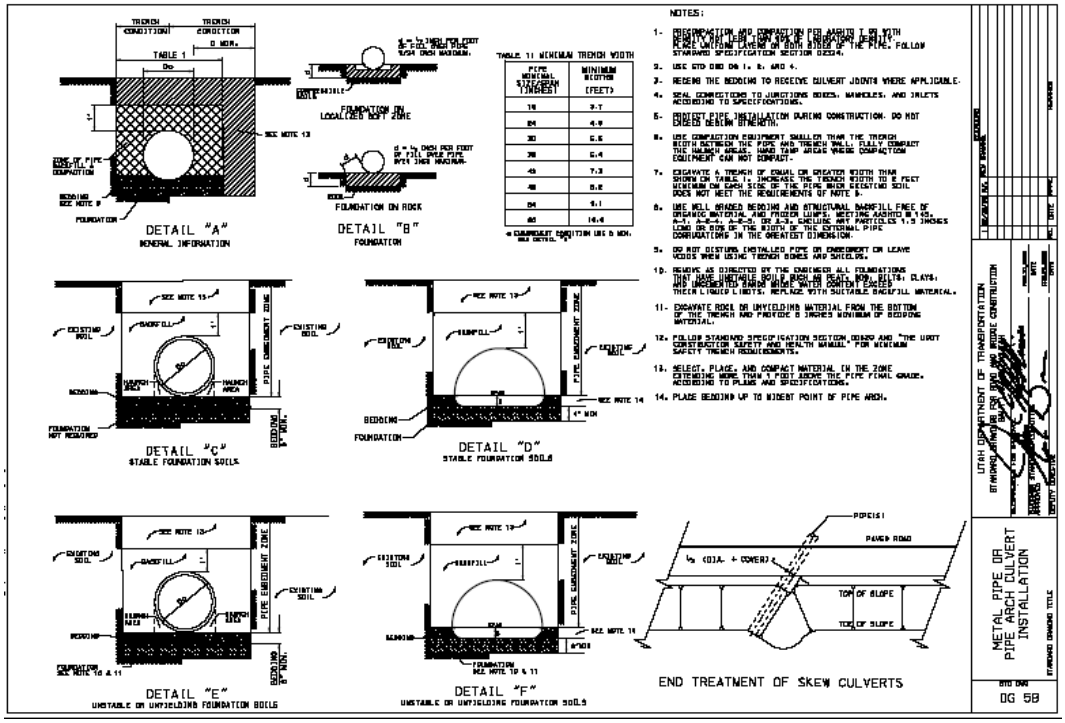
f. Check maximum fill heights using Standard Drawing DG 1 for Steel Pipe and Standard Drawing DG 2 for Aluminum Pipe.





Third: Monitor installation of product as directed by the Engineer.

Excavating, Trenching, Bedding and Backfill should conform to Standard Drawing DG 5B & Section 02317 of UDOT's Specifications and as well as the manufacturer's installation requirements.

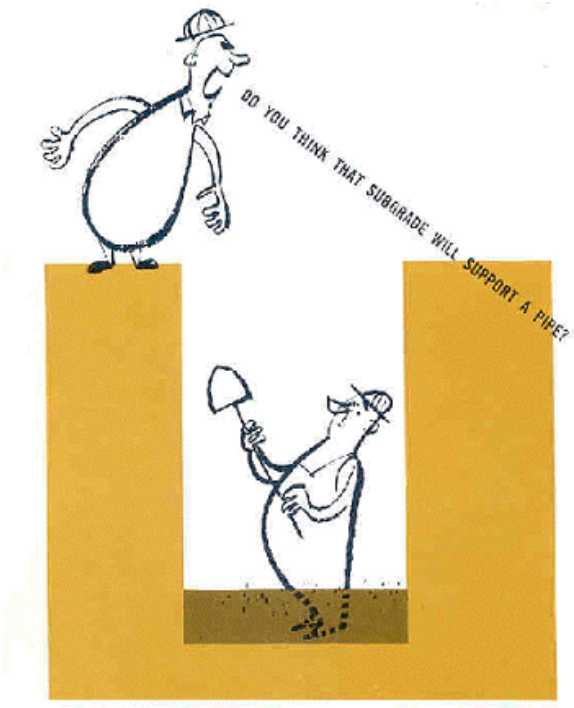


Reject any pipe damaged by careless unloading practices.

Note that unlike plastic pipe metal pipe can use both a trench installation or can be installed simultaneously with the embankment.

Hint: Measure trench width at the crown (top) of the pipe.

Make sure that the foundation & bedding is stable



Precompact trench bottom if necessary.

Hint: See Note 1 in DG 5B

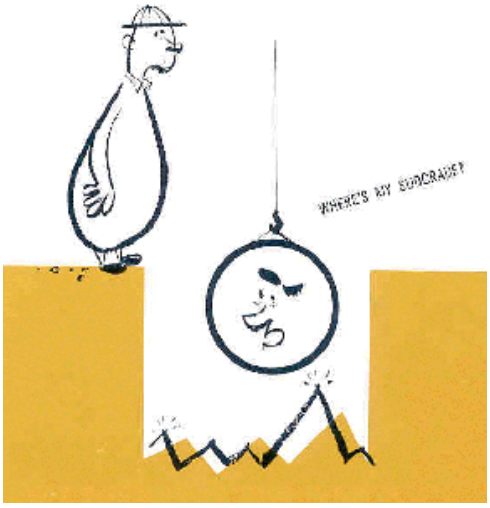
Without a stable foundation you will end up with a “roller-coaster” line & grade. If workers are sinking in the trench then materials are way too wet. When liquid Limit is exceeded it is impossible to compact foundation soils.

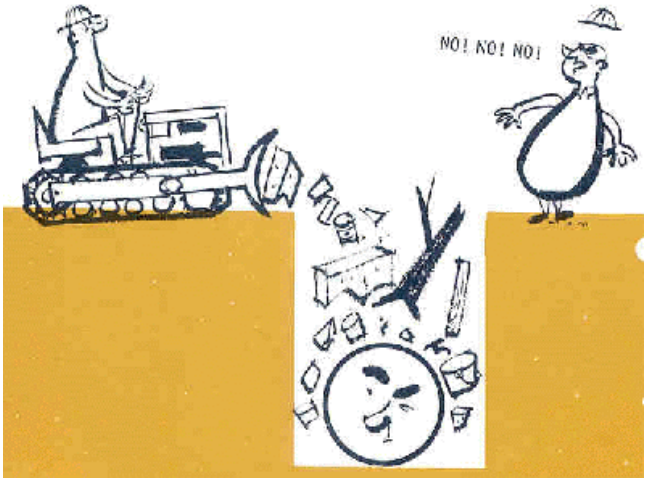
Hint: See Note 10 in DG 5B

Hint: Dewatering using sump pumps & diversion ditches is a common fix. If inherently unstable soils such as peat are present then the Contractor will have to undercut and replace with imported materials.

Make sure that only quality Bedding & Backfill Materials are being used.

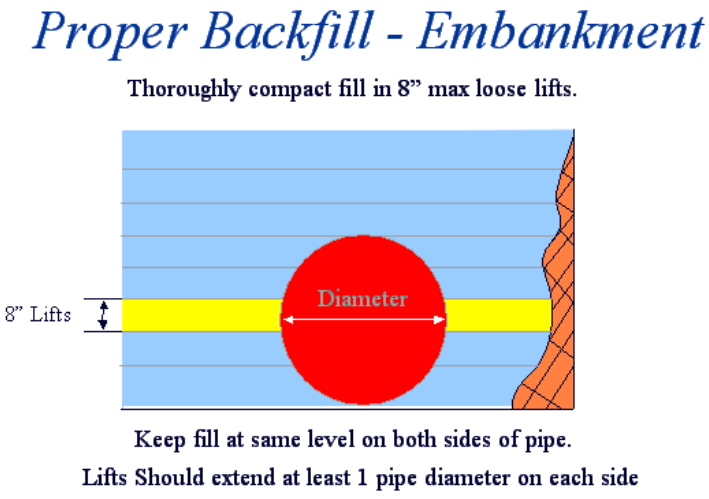
Hint: See Note 8 in DG 5B for acceptable materials





Do not allow backfill to be "dumped" in the trench. Backfill should be placed in uniform 8 inch loose lifts and properly compacted to 90% minimum density.

Hint: See Notes 1 & 8 in DG 5B for acceptable materials

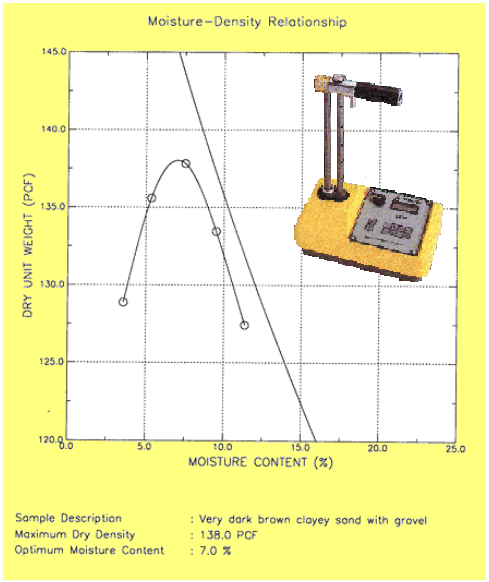


The haunch area will take a little extra care. Spot check to insure that the haunch is properly filled and compacted.

Hint: See Note 6 in DG 5B for acceptable methods. Use spud bars and shovels in tight areas.

Spot check compaction to insure that the backfill is being placed in balanced lifts (both sides of pipe at the same time) and properly compacted.

Hint: See Note 1 in DG 5B and manufacturer's recommendations for acceptable methods.



Remember the Contractor is responsible for performing all acceptance testing. You only need to witness it. He can do it with his own forces or he can utilize a third party testing company. Acceptance/Rejection is based on the following key criteria:

Excessive Horizontal and vertical alignment deviations.

Hint: Dumping fill on one side can easily shove a culvert out of horizontal alignment. Also poor trench construction where over excavated areas are not compacted can cause a pipe line to develop a "roller coaster" type of grade that encourages silting in the low spots reducing the flow capacity and making blockages & leakage at joints more likely.

Hint: There is no magic wand to fix alignment problems later on so "Spot Check" a pipe installation early in the project to insure that the Contractor is off to a good start.

Table 1 of 02610

Tolerances		
Installation Alignment Tolerances		
Design Grade	**Horizontal Deviation**	**Vertical Deviation ***
		inches/100feet
> 1 %	Horizontal joint deflections not to exceed industry standards	1 1/2
≤ 1 %		1
< 0.5 %		± 0.5

* For cross culverts increase tolerance by 50 percent.

Note- Deflections greater than 5% are unusual. The Engineer can accept somewhat higher deflections at a reduced Unit Bid Price. Deflections greater than 10% are a sign of serious installation problems.

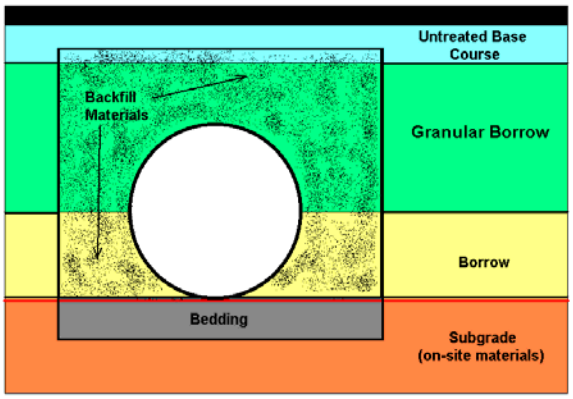
Excessive Pipe Barrel distortions; Examples of culverts which should be rejected.

The culvert on the left exhibits a “pear” shape with large radius flat barrel areas on either side of the crown. Deflections can increase over time and additional deflection could result in reverse curvature and culvert failure. The culvert on the right exhibits gross deflection and lack of symmetry indicates an inconsistent and structurally unreliable soil envelope surrounds the pipe barrel. Note- Specification 02610 requires the removal of such pipe showing more than 10 % deflection in any diametrical direction. Deflection tolerances are summarized in Table 4 of Specification 2610.

Hint: Peaking can easily occur when oversized equipment is used too close to the pipe as the backfill is placed. The photo on the left shows safer practice using a smaller compactor close to the culvert wall and a larger unit away from the culvert. The photo on the right shows a powerful hydro-hammer unit is being used very close to a pipe wall. The hydro hammer compacts more quickly but it takes a skilled operator to compact so close to a pipe without distorting or severely damaging the pipe. Spot check pipe where hydro hammers or hoe-pak compactors have been used and less than 4 feet of cover has been provided.

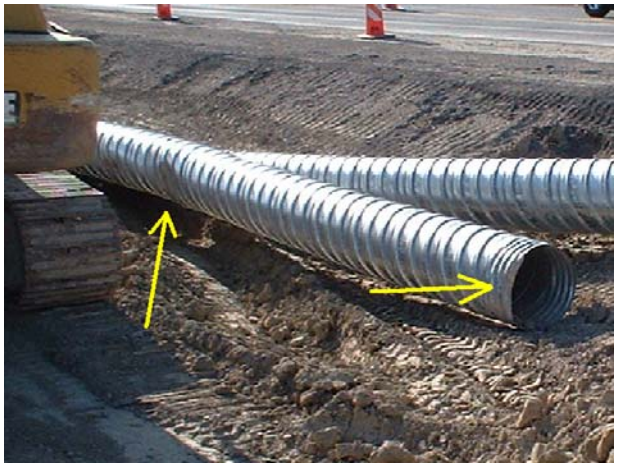
Materials requirements and compactive effort requirements change in the pavement section. Check project plans for thickness of UTBC in the pavement section and note that a T-180 and not a T-99 Proctor is normally called out. Shallow cover culverts are vulnerable to damage if heavy compaction equipment is run over the crown of the pipe. Lighter compactors and more passes may be needed directly over a pipe until proper compaction is achieved.

Hint: See Note 13 in DG 5B and manufacturer's recommendations for acceptable methods.



NOTE - In "above grade" pipe installations pipe backfill materials must meet the more stringent project specifications for the adjacent layers for gradation and compactive effort.

Reject damaged pipe:



Damage can be obvious such as the pipe in the left photo and the ding in the barrel of the pipe in the right photo or it can be less obvious such as the damage to the re-rolled annular joint corrugations to the pipe end. It is possible to repair the damage to the pipe end.

Hint: Some inspectors use paint to mark rejected pipe needing repair or removal.

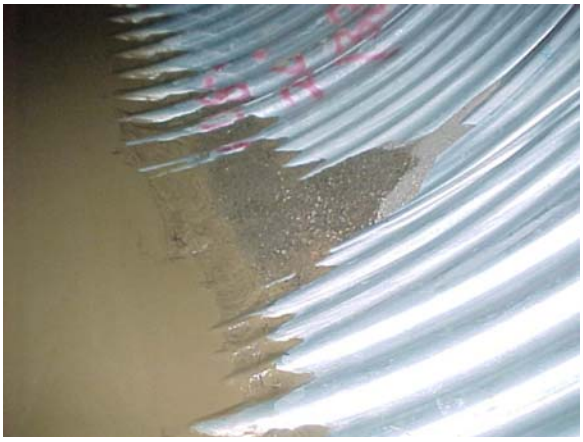
Reject damaged or defective pipe joints:

Joints include connections to manholes. The above photos show good connections well centered and using nonshrink grout to fill the annular space.

Examples of joints that should be rejected. The photo on the left shows gap in the annular space where nonshrink grout was not used and a gap has formed which will cause leakage. The photo on the right shows gravel "sandwiched" beneath the gasket material destroying the seal. Water will leak from the joint and flow through the gravel and saturate the subgrade.

Hint: These joints are easily repaired if caught before backfill is in place. They are difficult and expensive to repair later. These joints will easily fail the leak tests found in 02610. Do the Contractor a favor and point them out as soon as possible.

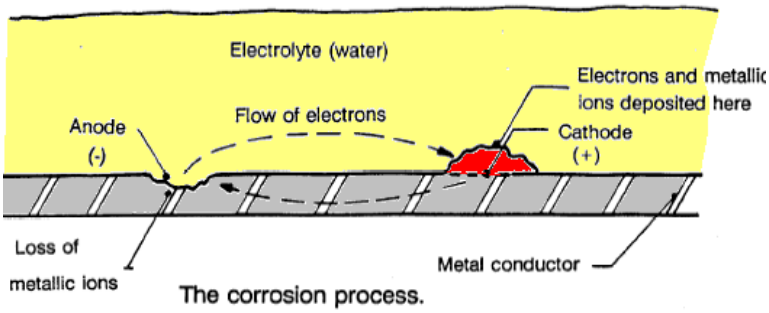
Reject joints which leak or are not soil tight & silt tight:



All irrigation pipe & storm drains should be water tight under normal conditions. Similarly all cross culverts are required to be soil tight & silt tight. Evidence of leakage or the piping of fines is a reason to reject such pipe. The photo on the left shows fine sands being washed into the pipe through a faulty joint causing a dip in the pavement above.

Reject Culverts with damaged coatings:

One of the reasons for rejecting metal pipe has to do with the condition of the pipe itself. Steel pipe uses a zinc and/or polymeric coating to protect the steel from quickly rusting. If that coating is missing or damaged the pipe will rust there first. If a pipe comes with it's zinc smelter coat significantly damaged, the damaged area should be painted with a zinc rich paint or it should be rejected. This also applies to damage at the ends of the pipe.

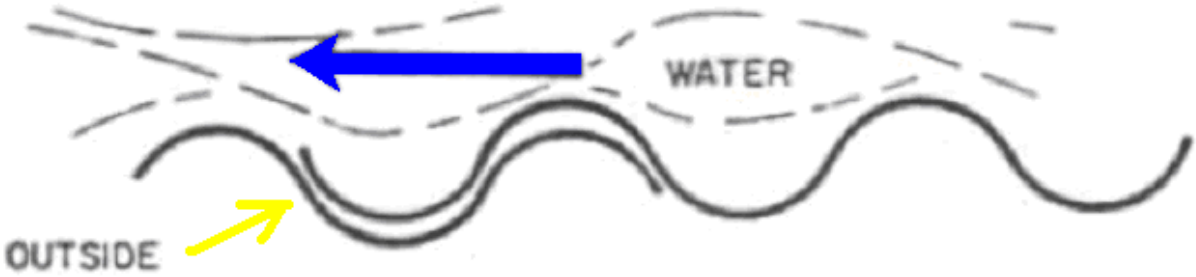


The corrosion process.

The photo on the left shows advanced corrosion where the polymeric coating was not properly bonded to the pipe. The corrosion process resembles a weak battery ; zinc coatings sacrifice themselves to protect the steel. Polymeric coatings slow electron flow and also protect the zinc from abrasion. Reject any pipe that have damaged coatings.

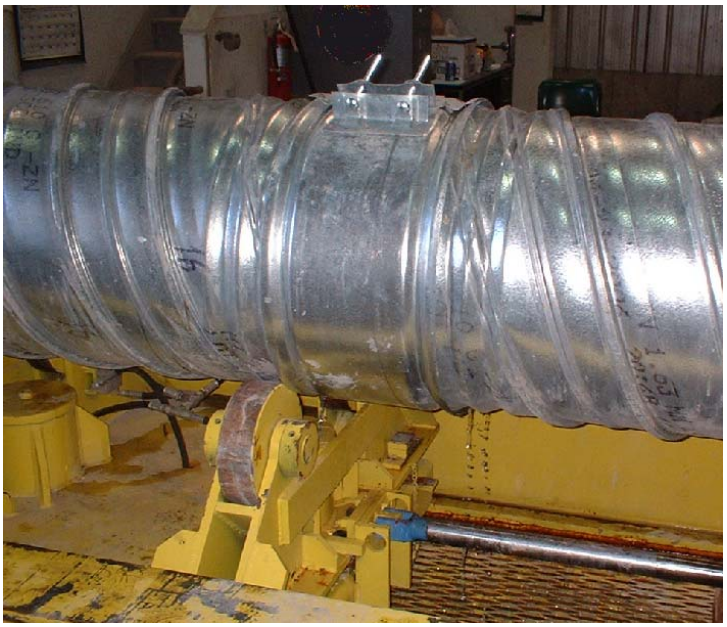
Hint: Depending upon the location and nature of the damage coatings can be repaired. Mark the top of repaired pipe so that repaired areas are not in the pipe invert.

CMP Pipe joints should be installed like shingles on a roof:



Hint: Note the flow direction and the resemblance to shingles on a roof. Place the outside (soil side) laps upstream.

Reject pipe joints with the wrong pressure ratings:



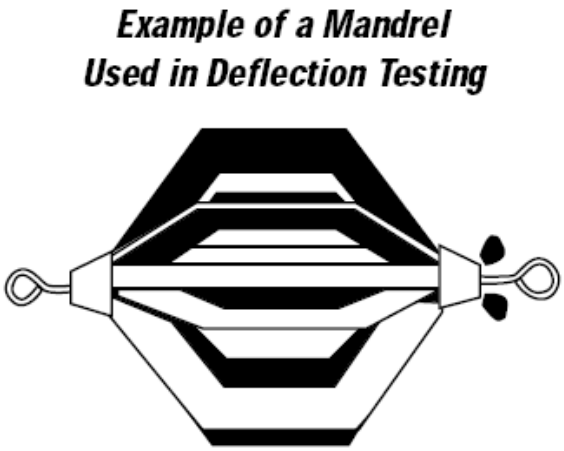
Remember that ***ALL*** storm drains & ***ALL*** irrigation pipe must have joints that will pass a 5-psi pressure test (or meet even stricter pressure requirements if specified in the plans).

Cross culverts must have joints that will pass a 3 psi pressure test in the laboratory.

Hint: Check your Certifications and make sure that you are getting the appropriate joints delivered. In general a wide gasketed joint is required for irrigation & storm drain pipe while lesser joint types are used in cross culvert installations

Note- Designers utilize pipe arches and structural plate pipes where only soil tight or silt tight joints are needed. These should be installed using the manufacturer's national recommendations and are not pressure rated.

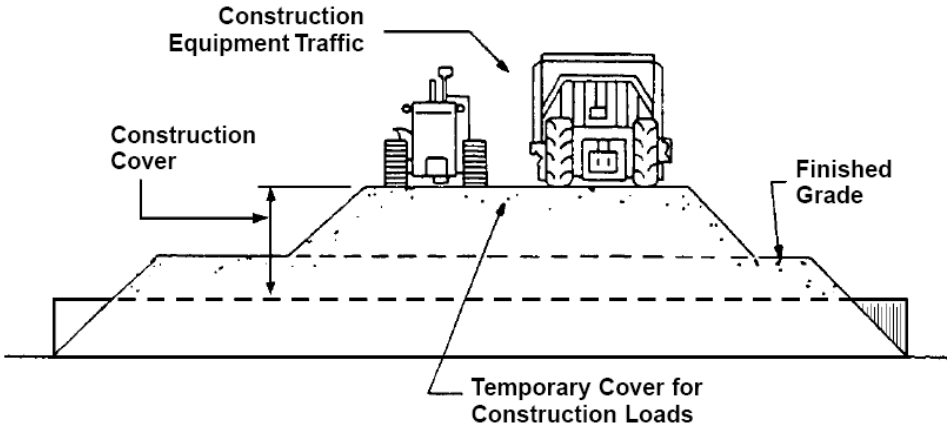
Measuring pipe distortions:



Distortions can be measured directly using a tape or other device or for smaller diameter culverts by using a mandrel. Direct measurement or mandrels test flexible pipes for excessive out-of-roundness or deflection. This testing ensures that flexible pipe has been properly bedded and back-filled to give optimum performance. Installed pipes should not exhibit ovaling or distortions greater then 5 percent of the nominal pipe diameter.
Hint: Mandrels are a “go-no go” type of device and must not be forced. Use of mandrels also insures that pipe are cleaned before acceptance.

Beware Heavy Construction Loadings:

Remember that pipe are designed to carry only “legal loads” and then only if properly installed with a well compacted soil envelope in place and a minimum cover of 2 feet over the crown of the pipe. During construction heavy truck loads can easily cause localized crushing and damage. A steel plate “bridge” or additional temporary cover is normally needed over pipe on haul roads or similar heavy construction load crossings.



Hint: Check pipe runs under haul roads & similar heavy construction loadings

CONTRACTOR QUALITY CONTROL SUMMARY

A. Provide adequate cover or protection for all pipe during project construction. Replace all damaged pipe before acceptance by the Department.

B. The following are some causes for rejection:
   1. Irregular or distorted shape (not as provided or designed)
   2. Dents or bends
   3. Damaged, broken, delaminated or scaled coating
   4. Loose bolts or nuts
   5. Uneven laps
   6. Improper fitting joints
   7. Any damage which compromises the functionality and design life of the pipe.

C. Coatings:

   1. Department will take a representative sample from each lot furnished to conduct verification testing.

Minimum Contractor special inspection and special testing frequencies:

The Contractor must inspect 25 percent of all cross culvert, storm drain installations, and irrigation pipe units on the project.

Minimum inspection and testing frequencies are defined in Table 2 of 02610.

Note that inspection and testing must take place prior to placing pavement.

Sample units to be inspected are selected by the Engineer and not by the Contractor.

The Contractor must test any pipes with apparent defects as directed by the engineer.

After 25% of the sample units have been inspected and tested the Department will pay the cost of any requested additional tests only if the tests pass.

The costs of additional tests that fail are the responsibility of the Contractor.

Examples of sample units

The entire length of a cross culvert counts as one sample unit.

A run of pipe between two distribution boxes in an irrigation system counts as one sample unit.

A run of pipe between two catch basins in a storm drain counts as one sample unit.

Do the Visual Inspection First:

The inspection and testing program ramps up depending upon the results of the visual inspection.

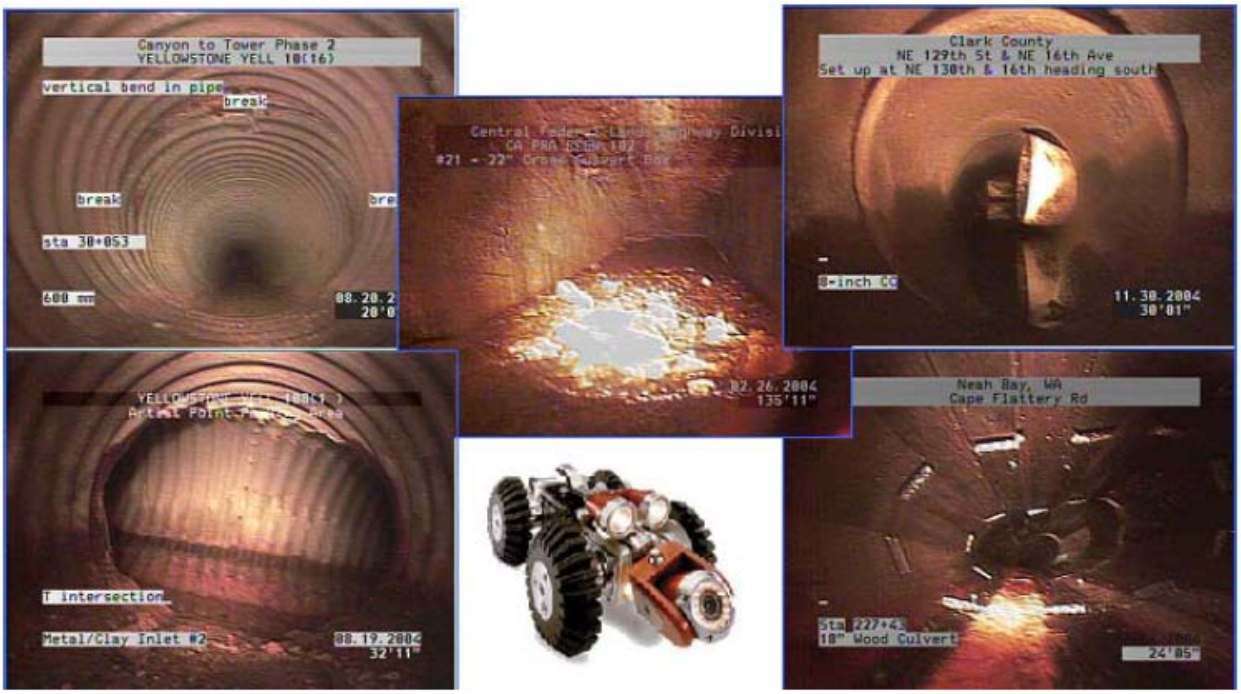
For smaller diameter pipe the contractor must provide and use a mobile color video camera with an appropriate light to show the interior of the pipe. The camera must be able to move inside the pipe barrel and to be controlled remotely by the inspector. See Table 2 of 02610.

The contractor must provide a remote monitor and a recording apparatus for this camera to both view in real time and record the condition of the installed pipe.

The contractor must provide a digital copy of the pipe inspection video recording to the Engineer as a permanent record of the inspection.

The Contractor must repair or replace damaged or improperly installed pipes in a sample unit at the direction of the Engineer.

If, in the opinion of the Engineer, the visual inspection shows a satisfactory installation and any necessary repairs or damaged pipes are replaced then the minimum testing and inspection is complete and no additional testing is required.



If the Visual Inspection shows deformation problems:

When the visual inspection shows deformation problems the Engineer can require that either manual measurements or a Mandrel Test be performed on the questionable run of pipe.

For smaller diameter pipe test for out of roundness or other deformation by *hand pulling* a fabricated mandrel through the sample unit. For larger diameter pipe deformation can be by tape or other measuring method acceptable to the Engineer.

The mandrel used must be acceptable to the Engineer and have an effective diameter equal to 95 percent of the nominal inside diameter of the pipe.

Verify that any distortions in installed pipes sampled meet the criteria given in Table 2.

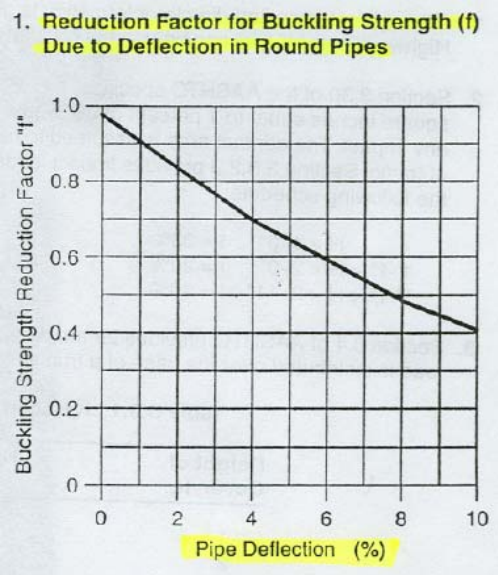
If, in the opinion of the Engineer it is in the best interests of the Department to leave a culvert in place and the distortions exceed 5% and do not exceed 10 percent then either the Contractor must provide to the Engineer an engineering analysis certifying the structural and hydraulic integrity of the pipe, stamped by a professional engineer registered in Utah or if an engineering analysis is not performed certifying the structural and hydraulic integrity of the pipe the pay reduction schedule found in Table 4 of 02610 will apply for sample units left in place that have pipes that do not meet deformation requirements.

Table 4

Payment Reductions	
PIPE DEFLECTION MEASURED	
Amount of Deflection (%)	Payment
0.0 to 5	100% of the Unit Bid Price
5.1 to 9.9	75% of the Unit Bid Price
10 or greater	Remove and Replace

Why an Engineering Analysis can be important and a pay reduction is warranted:

Excessive distortions can cause buckling failures. This chart shows the reduction in buckling strength that an out of round pipe experiences as distortions increase.



A steel pipe which deflects 5% looses 35% of it's buckling strength. A pipe which deflects 10% looses 60% of it's buckling strength and so on.

Deflections greater than 10% are "off the chart" and not acceptable. Whether there is adequate strength left in a distorted pipe requires an analysis of the safe buckling loads as well as other potential failure modes.

When the Visual Inspection shows joint problems in Storm Drains & Irrigation pipes:

When the visual inspection shows potential joint problems the Engineer can require that either an air or water test be performed on the questionable run of pipe to demonstrate joint integrity.

Test all steel pipes that have joints showing visible gaps, defects, or any other problem using either an Air Test of individual joints an Exfiltration (Water) Test. The Exfiltration test utilizes the less strict leakage rates given in Table 3 of 02610. **[Note that improperly performed air tests can be very dangerous strictly follow the Test Method protocols and Utah Occupation Safety and Health Regulations.]**

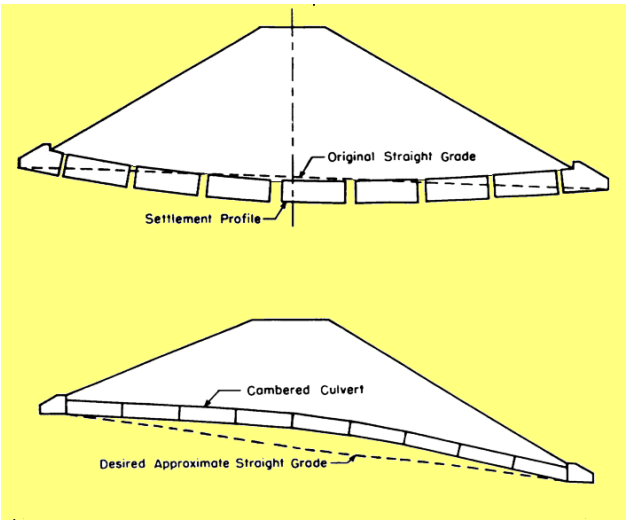
The Contractor must locate the source or sources of leakage and repair damaged storm drain or irrigation systems that do not pass the test.

The Contractor must repair according to the manufacturer's recommendations pipes that fail the Joint Test at no cost to the Department and retest the repaired pipes.

The Contractor must remove and replace pipes if they fail the retest.

Miscellaneous Design Elements

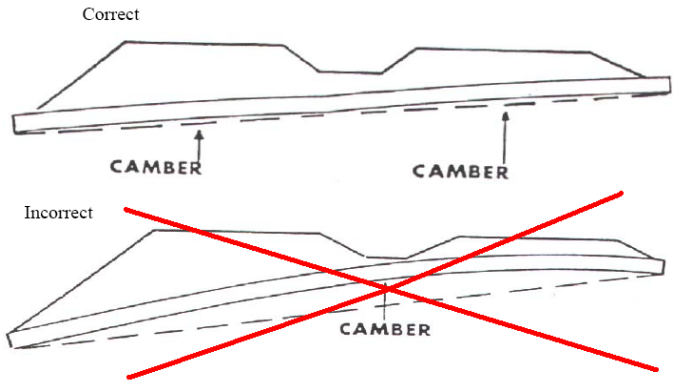
Camber Requirements



Cambering is the practice of raising the central portion of the pipe run so that the long term settlement caused by the fill will not cause a sag in the pipe which will trap sediment and reduce flow capacity. Ideally camber should match the expected long term expected settlement which depends on the height of the fill and the nature of the subgrade. The Geotech Division should be consulted for an estimate of long term settlement. One thing that limits the amount of camber that can be put in a pipe is drop. Drop is the difference between inlet and outlet elevations. Water flows down hill so the middle of the pipe should not be raised higher than the inlet.

When indicated on the drawings, camber pipe upward from a chord through the inlet and outlet inverts an ordinate amount equal to one percent of the pipe length. Develop camber on a parabolic curve. If the mid-point elevation on the parabolic curve as designed exceeds the elevation of the inlet invert, reduce the amount of camber or increase the pipe gradient.

Camber is installed differently when a cross culvert must pass under twin embankments as often occurs under an interstate highway. Camber should be installed just like there were two separate pipes under two separate embankments with care taken to provide continuity to the culvert gradeline as illustrated below:



Paved Inverts:

Use corrugated steel pipe or pipe arch and complete backfill and embankment over the pipe before placing paved invert material.

Use 10 gage wire fabric with wire spaced at 6 inch centers and arc-weld the wire mesh reinforcement to the corrugation at not more than 2 ft centers.

Place concrete at least 2 inches above the crest of the corrugations, at least 1/4 of the circumference of round pipe, or the span width of arch pipe.
Finish the concrete to a floated surface finish.

After curing, coat the joint between the pipe and concrete with liquid asphalt at a rate 0.9 gal/yd^2 of residual asphalt. Coat 6 inches above and below the joints.